

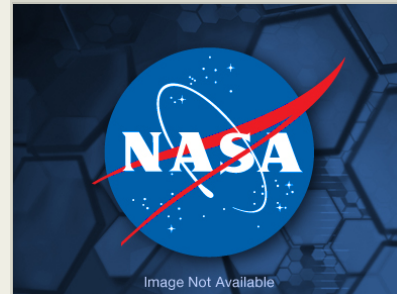
On-orbit figure sensing and figure correction control for 0.5 arc-second adjustable X-ray optics

Completed Technology Project (2015 - 2017)



Project Introduction

This investigation seeks to develop the technology to directly monitor on-orbit changes to imaging performance of adjustable X-ray optics so as to be able to efficiently correct adverse changes at a level consistent with 0.5 arc-second X-ray telescope imaging. Adjustable X-ray optics employ thin film piezoelectric material deposited on the back of a thin glass Wolter mirror segment to introduce localized stresses in the mirror. These stresses are used in a deterministic way to improve mirror figure from ~ 10 arc-sec, half power diameter (HPD), to 0.5 arc-sec, HPD, without the need for a heavy reaction structure. This is a realizable technology for potential future X-ray telescope missions with 0.5 arc-second resolution and several square meters effective area, such as SMART-X. We are pursuing such mirror development under an existing APRA grant. Here we propose a new investigation to accomplish the monitoring and control of the mirrors by monitoring the health of the piezoelectric actuators of the adjustable optics to a level consistent with 0.5 arcsec imaging. Such measurements are beyond the capability of conventional, thin metal film strain gauges using DC measurements. Instead, we propose to develop the technology to deposit different types of strain gauges (metal film, semiconductor) directly on the piezoelectric cells; to investigate the use of additional thin layers of piezoelectric materials such as lead zirconate titanate or zinc oxide as strain and temperature gauges; and to use AC measurement of strain gauges for precise measurement of piezoelectric adjuster performance. The intent is to use this information to correct changes in mirror shape by adjusting the voltages on the piezoelectric adjusters. Adjustable X-ray optics are designed to meet the challenge of large collecting area and high angular resolution. The mirrors are called adjustable rather than active as mirror figure error is corrected (adjusted) once or infrequently, as opposed to being changed constantly at several cycles/sec (active). In our approach, the mirror figure is corrected based on ground measurements, accounting for figure errors due to mirror manufacturing, mounting induced deformations, modeled gravity release, and modeled on-orbit thermal effects. The piezoelectric strain monitoring we seek to develop in this program extends adjustable mirror technology development, as it enables efficient adjustment and correction of mirror figure on-orbit, as required. This unprecedented level of system robustness will make telescopes less expensive to build because requirements for the non-optical systems can be looser, and it will also make the system more resistant to degradation, promoting mission success. The largest drivers for changes from ground calibration to on-orbit performance are piezoelectric material aging and an unexpected thermal environment (i.e., larger gradients than modeled or other thermal control system problem). Developing the capability to accurately monitor the health of each piezoelectric cell and the local mirror surface temperature will enable the real time sensing of any of these potential issues, help determine the cause, and enable corrections via updating models of on-orbit conditions and re-optimizing the required piezoelectric cell voltages for mirror figure correction. Our 3 year research program includes the development of the strain



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Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Astrophysics Research and Analysis

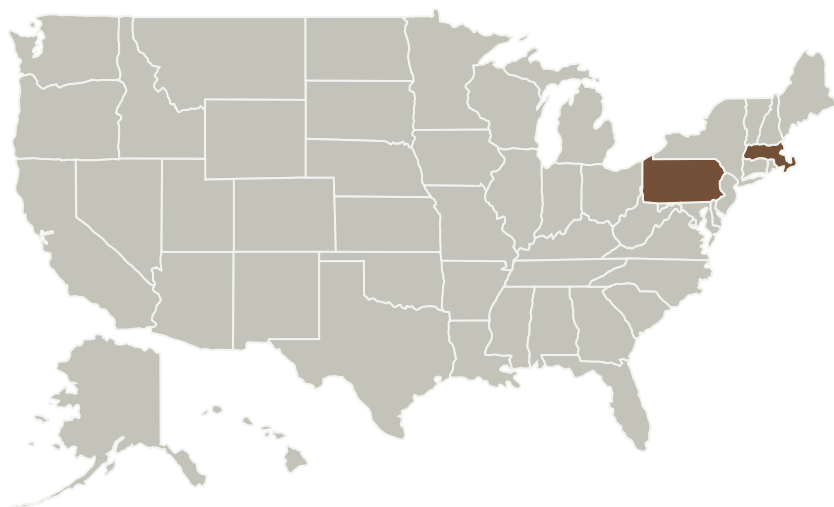
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monitoring technology, its deposition on the adjustable optics, modeling and performance simulation, accelerated lifetime testing, and optical and electrical metrology of sample adjustable optics that incorporate monitoring sensors. Development of the capability to remotely monitor piezo performance and temperature to necessary precision will vastly improve reliability of the SMART-X mission concept, or the sub-arc-second X-ray Surveyor mission described in the 2013 NASA Astrophysics Roadmap, 'Enduring Quests Daring Visions.'

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Smithsonian Astrophysical Observatory(SAO)	Supporting Organization	US Government	Cambridge, Massachusetts

Primary U.S. Work Locations	
Massachusetts	Pennsylvania

Project Management

Program Director:

Michael A Garcia

Program Manager:

Dominic J Benford

Principal Investigator:

Paul Reid

Co-Investigators:

Daniel A Schwartz
 Thomas N Jackson
 Raegan L Johnson
 David N Burrows
 Michael Griffith
 Vincenzo Cotroneo
 Alexey Vikhlinin
 Ryan Allured
 Rudeger H Wilke
 Stuart Mcmudloch
 Susan Trolie-mckinstry

Technology Areas

Primary:

- TX08 Sensors and Instruments
 - TX08.2 Observatories
 - TX08.2.1 Mirror Systems

Target Destination

Outside the Solar System